The Ohio State University
Campus as a Living Laboratory

Solar Panels: Reducing Ohio State's Carbon Footprint

Ben Robinson, Kaitlyn Wagner, Peter Bucher, Destiny Allen

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A program of Energy Services and Sustainability
Aparna Dial, University Director, Energy Services and Sustainability
Dial.15@osu.edu

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Executive Summary

The green movement at Ohio State is something that the university has been committed to for over a decade. One of the biggest staples of this movement was the endorsement of *The Ohio State University Climate Action Plan* in April of 2011. This laid out Ohio State's current environmental standing, the plans they have already enacted, and where the university wishes to be in the future. This document set the stage for the solar panel project we propose for Ohio State. Once completed, this project will accomplish many of the goals the university states in their climate action plan.

The Ohio Union has available space that can be used for solar energy production. Ohio State's Climate Action Plan requires that Ohio State be carbon neutral by 2050, and this means that they must reduce dependency on coal-power. One way that less energy can be bought from coal power plants is to install solar panels on the Ohio Union. Since the Union uses more electricity than most campus buildings and is also quite new, the Union has been chosen for solar panel installation. Between flat and slanted roof panels, the solar arrays can produce a small amount of energy for this campus building. After installation of solar arrays, the Union will be an example of the renewable energy movement at Ohio State, as well as producing energy for the building.

The government has in place many incentives to help motivate people to think about the environment. Luckily, Ohio State is already motivated. This is why analyzing the cost of electric in use by the Ohio Union and the amount of money that can be saved through the process of installing solar systems is important. It is eye opening and an easy way to support and idea. Competition is also a way to push for the need to care about the environment. By showing what other Universities are doing causes a movement amongst other Universities and can encourage the people who need encouragement to support the installation of a solar system on the Ohio Union.

Introduction

Being one of the largest universities in the country with over 55,000 students, Ohio State has an incredibly large demand for resources. The amount of electricity, natural gas, and steam used for the Columbus campus alone rivals that of many small cities. This is a large reason why, in 2008, University President Gordon Gee signed the American College and University Presidents' Climate Commitment (ACUPCC) for The Ohio State University. The ACUPCC is a set of strategies intended to guide communities that aim to reduce their greenhouse gas emissions, specifically carbon emissions.

Gordon Gee states the importance this act will have in shaping the university's future,

> "At Ohio State, we also believe that our future competitiveness depends on being innovative leaders, developing the technologies and embracing the cultural changes necessary to thrive in a world that must reduce carbon emissions (Climate Action Plan, 2011)."

The university has already started taking action to achieve this carbon neutral goal by signing a 20 year agreement with the Blue Creek Wind Farm in Northwestern Ohio. The agreement states that OSU is to purchase 50 megawatts (MW) of wind energy annually which will supply 25% of the campus' electricity needs (Pyle, 2013).

However, to completely eliminate carbon emissions, the pursuit of additional sources of renewable energy must occur. The use of solar panels to further reduce carbon-based electricity needs for OSU's main campus is the most realistic option due to similar project's past success. The first task will be deciding on which set-up and technology to use. There are a number of options in terms of panel types and mounting systems. Finding eligible buildings will be a major portion of the project. Due to the university's rapid turnover of buildings, only select sites are realistic options. Finally, the financial aspect will need to be examined to ensure the benefits outweigh the cost. There will be high initial costs to implement a solar panel project, but the long term benefit cost analysis will show that it is a pertinent investment for The Ohio State University.

The Climate Action Plan

Ohio State's commitment to sustainable practices campus wide began in 2003. A project was born to convert the CABS bus fleet from running on gasoline, to running on B20 biodiesel. This was the beginning of a mindset change across the university, and the ripple effect has been unending for the last 10 years, Gordon Gee signing the

ACUPCC created a centerpiece for this new movement. In April of 2011, the university published their strategy for where they were going to take the ACUPCC in Columbus, OH. *The Ohio State University Climate Action Plan*, better known as the climate action plan (CAP), was officially endorsed on the 6th of April, 2011.

This landmark document evaluates the state of the campus in a range of areas. Along with evaluation, the CAP states several goals that have been adopted to further progress Ohio State and keep it among the leading universities in America. These goals include: "Plan for carbon neutrality by 2050, expand the university's renewable energy portfolio, improve fleet purchasing standards, and work toward zero waste goal", among others (Climate Action Plan, 2011). Due to the wide range of these goals, no one project or effort can be the only answer to deliver Ohio State to where they want to be in 2050. The efforts and collaboration of many will be required. Our project proposal will be mainly aimed at the goals seeking to reach carbon neutrality and to expand the university's renewable energy portfolio.

<u>The State of Ohio State</u>

The main campus at Ohio State used 574,013,929 kilowatt hours/year (kWh/yr) of electricity in 2009, and of this, 73% came from the burning of coal (Fig. 1; Climate Action Plan, 2011). The CAP states that Ohio State's greenhouse gas (GHG) emissions for 2009 totaled approximately 757,051 million metric tons of carbon dioxide equivalent ($MTCO_2e/yr$) (Climate Action Plan, 2011). The largest contributor to Ohio State's annual GHG emissions came from the electricity grid (58%). This heavy dependence on coal burning power plants will easily be the biggest obstacle that Ohio State will need to overcome to reach their 2050

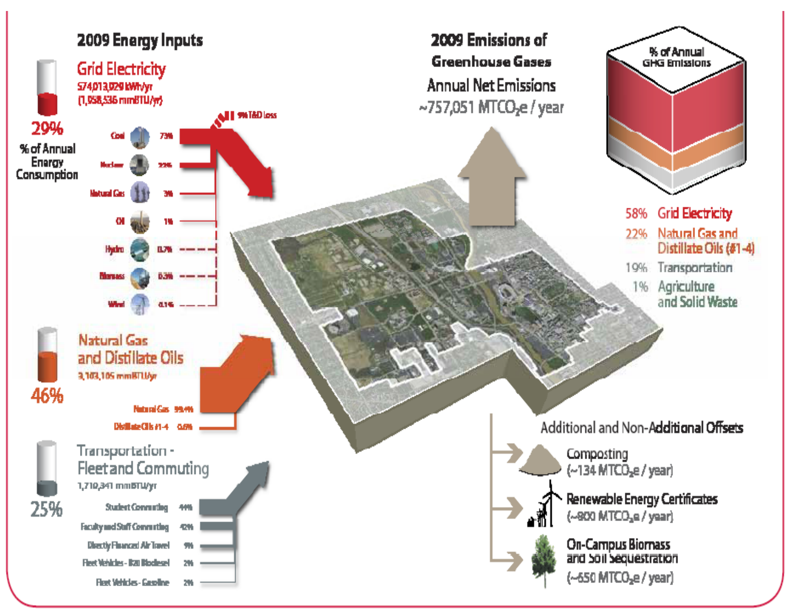

Figure 1. Energy Inputs and Greenhouse Gas Emissions
Image: © Mithun. All rights reserved.
Data: The Ohio State University CACP

carbon neutral goal. Projects that seek to input electricity to the campus grid from sources that don't emit large amounts of carbon dioxide (CO_2) need to be a priority for the university to begin reducing the annual GHG emissions.

Why Solar?

As previously mentioned, the achievement of becoming a carbon neutral campus by the year 2050 will not be possible unless there is collaboration from many different "carbon-friendly" sources. Solar is one such source that does not currently have a predominant presence on Ohio State's campus. Primarily, solar energy can be introduced into the OSU grid on a utility scale size or on a building-to-building basis. A utility scale project would be the best way to take a large portion out of the university's energy needs much like the purchasing of the windmill farm electricity credits. However, we are proposing that a building-to-building project come to life to see how well solar panels would work for Ohio State.

A solar panel project would have other benefits aside from reducing carbon emissions from electricity use. The eventual financial benefits will be later discussed in the paper. Aside from making fiscal sense, this project will benefit other goals that Ohio State wishes to accomplish in the CAP, such as education and research. Once the solar panel project is completed, the technical aspects of the project would be an incredible learning opportunity for any number of engineering students at the university. Along with Ohio State students, visitors to the university could have the opportunity to gain knowledge about sustainable technologies. Being one of the leading research universities in the country, OSU could further advance their sustainability research by studying the effects these solar panels would have.

In addition to goals stated in the CAP, this solar panel project would be an excellent public relations move for Ohio State. Ohio State has already shown that they are committed to being more environmentally friendly by the signing of the ACUPCC; this project would further show their commitment to this and their version of the CAP. Unlike the windmill farm credits, a solar panel project would be highly visible to the public and physically located on the Columbus Campus. The benefits of such a project being completed exceed carbon emission reduction and saving money on an electric bill.

Solar panel projects of a wide range of sizes have been found to produce economic benefits for those that embark on them. Unlike most of those projects, this university project will truly create a living laboratory. As with any project at Ohio State, they will open bidding to installation companies to come in and complete the task. Ohio State will need to begin this process by determining the ideal set-up that would best suit the university's needs.

Why Ohio Union?

Another step to designing a solar roof is finding the best campus roof for the array. Not only does the roof need to have plenty of empty space, but it must be visible to many visitors and students to make an educational impact. In a time when there is a large push for alternative energy, Ohio State must diversify their electric sources in order to lead the race to become a carbon-neutral campus by 2050. The Ohio Union is the campus building that provides adequate roof space and appropriate access to the public. The Ohio Union is only three years old, and therefore is one of Ohio State's newest facilities. Installing solar arrays on a new building is wise, because panels are unlikely to outlive the building itself. The Ohio Union is also a Leadership Energy Environment and Design (LEED) silver certified building, meaning that it was designed and constructed to optimize integrated environmental and economic factors. Despite this fact, the Union still uses an astounding 6,052.5 Btu/GSF per month (Energy, 2013). It is obvious that the Union's reputation as a "green" building needs to be continued, and reducing the energy usage by construction of a solar roof would help this goal.

The Ohio Union contains 31, 355 square feet of clear roof

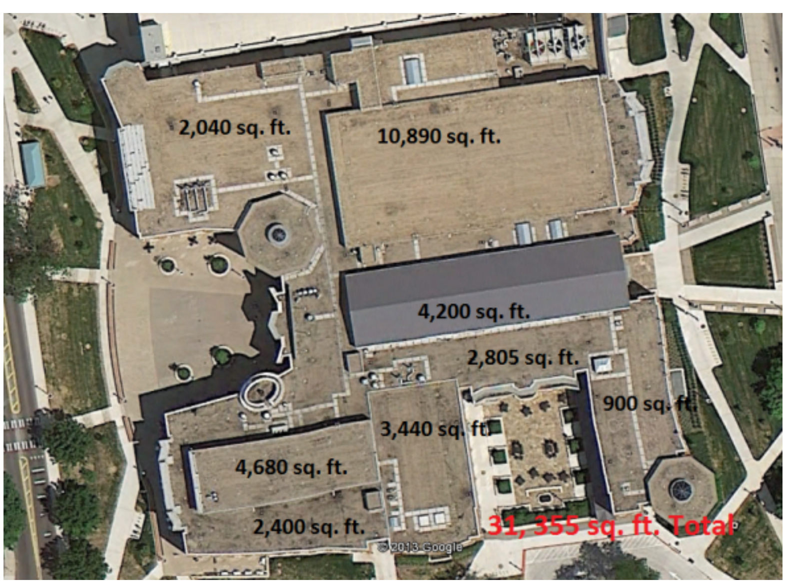

Figure 2. (ArcGIS Explorer, 2011)

space (Fig.2). This number is a combination of flat and slanted roof space. Fig. 4 displays the location and extent of the roof space. The space designated in flat roof space could be a combination of solar arrays that would require a special design that is specific to mounting panels on a flat roof. The space designated as, “4,200 sq.ft.,” is located on a slanted roof that faces almost directly south. In the northern hemisphere, south facing features receive more sunlight than those facing the north. Therefore, flat roof panels would be angled and spaced so that they would receive optimum sunlight. Obviously, solar arrays could be installed on the ground, but there are benefits to solar roofs.

Why on a Roof?

The proposed solar array would be an example of on-site electricity production. Ohio State’s Columbus Campus is one of the largest campuses in the nation. However, the city of Columbus currently surrounds the campus on all sides, restricting any further expansion. Because of the limited space, the proposed solar system would be located on a roof. Currently, the Union roof contains thousands of square feet of unused space that is available for installation of solar arrays. If solar panels would cover the extent of the roof, the electricity produced would be about 5% of the Union’s usage (Solar Reviews, 2013). It is clear that the solar panels would exist as a supplement to other renewables. Solar energy at the small-scale level is not powerful enough to produce enough energy for an entire building. Installation of solar panels would diversify Ohio State’s renewable energy résumé, and take another step towards a carbon-neutral campus. There are two different ways to apply solar panels on a roof.

Flat Roof Method

Most solar roofs are located on slanted roofs, but the Union contains considerably more flat roof space than slanted roof space. A US patent does exist for solar panels on flat roofs, Patent number 7,921,843. This patent explains the mounting system used for flat roofs in detail, (Fig. 3). The mounting system is a common sheet of metal that includes a first and second mounting ledge, a flat base section, and an inclined section. The metal sheet can be manufactured out of aluminum, stainless steel, or galvanized sheet metal. Mounting angles vary from region to region, and between 10 and 35 degrees of angle (Rawlings 2011). Weights are placed in the troughs between the panels, because supports cannot be fastened to an already existing roof. Weights should be made of concrete, because they are weather resistant and inexpensive. Microinverters will be located in between weights in the troughs. The design of this mounting system exists to provide a light, easy, and quick installation of solar arrays (Rawlings 2011). Flat roof systems are not the only way to efficiently mount solar panels on a roof.

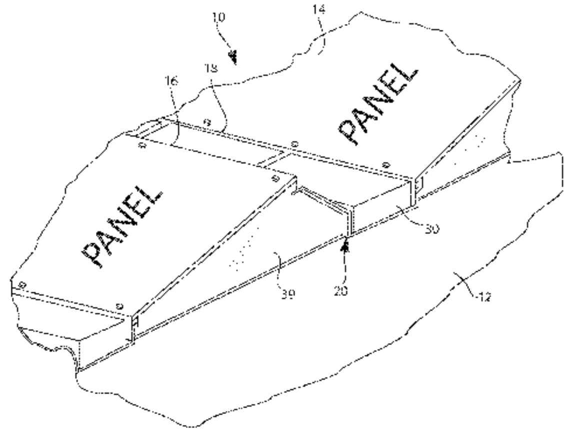

Figure 3. Perspective view of the segment of the solar roof array (Rawlings 2011).

Slanted Roof

The Union's roof does contain about 4,200 square feet of slanted roof. The design for the Union's slanted solar roof system will follow Oberlin College's solar roof on their Adam Joseph Lewis Center, and the US Patent 5,647,915 (Zukerman, 1997). Oberlin's AJLC roof is about 4,800 square feet, which is slightly more than the Union's 4,200 square feet (Fig. 4) (Murray 2004). Their three arrays, installed in 2000, each contain 15 kW of monocrystalline PV panels. In total, there are 690 85 W modules. A new 250 W Helios solar panel costs $310, when bought in pallets of 25 (Compare, 2013). Each panel is 17.9 square feet in area, meaning that the Union's south roof could hold about 234 of these panels. This would amount to a 58.5 kW system on the Union roof, which is very similar to Oberlin's. The Union's slanted roof could then potentially produce 702 kWh per day from this system. The Union uses about 17,000 kWh per day, meaning that with these new panels, the slanted roof solar array could produce 4.1% of the Union's daily energy consumption.

Figure 4. Aerial view of Oberlin's AJLC (DeFreitans 2012)

The US patent 5,647,915 gives guidance for construction of a slanted roof array. Arranging panels in an array like the patent suggests provides a weatherproof and sealed system that is a roof element and electricity-producing system in one. The panels are covered in a polymeric pane that blocks moisture from entering the module. Modules are attached to the roof at the anchor blocks, and each panel is connected to the other and sealed with a waterproof flashing (Zukerman, 1997). Designing solar roofs is not a flawless system, and the reality of solar panels may differ from these plans.

Solar Panel Reality

The numbers shown in the preceding sections cause the idea of solar panels to appear flawless. In reality, only estimations can be given for solar panel energy output. As a disclaimer, the numbers in the preceding sections are a combination of estimations and personal calculations. Also in reality, roofs cannot hold unlimited weight. Eric Faulk, an employee on the maintenance staff for the Ohio Union, confirmed that solar panels could potentially exist on the flat and slanted roof sections of the Union. However, the pattern in which they would be located would be dependent on the location of the support beams underneath the roof (Faulk, E., personal communication). An engineer would need to compare the weight of the panels, which are roughly 50 pounds each, with the weight tolerance of the support beams (Compare, 2013). Because of this, not every square foot of roof space could be used. An expert's opinion on the possibility of solar panels on the Union is crucial to the possibility of this project's success.

Technicalities of Solar Panels

There are two ways to harness solar energy to be used by humans. Photovoltaic solar panels convert solar energy into electricity. This is beneficial if you want to power your building independently of the electric companies. These solar panels have a high efficiency, usually ranging from 20 to 25%. To obtain the electricity, the solar energy is converted to a flow of electrons that move across the solar panel, and from there the electrons go into an inverter. Then, the inverter converts the electrons to usable electricity which can be fed into the power grid and made available for use. Photovoltaic cells are more expensive than their counterpart, solar thermal cells, which do not produce electricity. Instead, they heat water for your building or, more commonly, a pool. These panels are placed on the roof and the sun heats the water. It would be best to use photovoltaic solar panels on the roof of the union because electricity would be generated and the efficiency is high compared to other alternative technologies.

Photovoltaic solar panels are made in a few different styles. The pure silicon structure produces the highest efficiency because the electrons are more closely aligned. This makes energy transfer from sun to electricity faster and easier. The refining process of silicon is expensive, which makes the pure silicon style expensive as well. The cheaper option would be to use a semi-conductor alloy. This is a mixture of semi-conductors and because they do not have such a stringent refinery, it is cheaper to make. Even though the pure silicon model is expensive, it would be best to use this type because the higher efficiency would result in more electricity produced. The more electricity that can be produced, the faster the panel system can be paid off and the faster Ohio State would be able to make profits off the investment.

There is an innovative technology that is changing previous notions of solar power. It can increase the efficiency of PV panels substantially. This technology is microinverters. Instead of all panels feeding into one inverter, each panel will have its own microinverter. This allows for a smaller distance for the electrons to travel, making energy loss smaller.

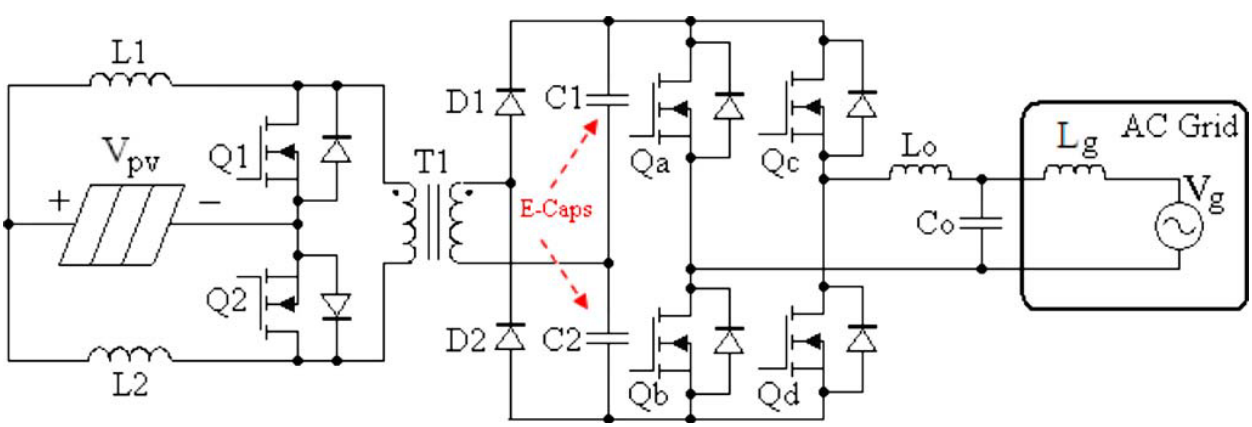

Figure 5. (Chiu, 2013): Depicts the proper location of E-Caps between DC-DC and DC-AC (D1 Δ C1 and Qa Δ Qc)

The most basic design of a two-stage microinverter includes a DC-DC converter which increases solar energy and voltage. That increased energy goes into the DC-AC microinverter. This step is crucial because the energy is maximized through this process. The potential energy is greater than previously thought. An electrolytic capacitor (E-caps) is recommended to place between the DC-DC converter and the DC-AC inverter (Fig.5). This is because even though energy output is increased, there is still some energy loss. The E-caps will increase efficiency. If Ohio State were to implement this technology on photovoltaic solar panels, then the payback could potentially be faster.

Solar energy is an important aspect to consider when thinking of alternative energies; however, Ohio is not particularly known for year round sun. Latitude affects irradiance of the sun. The closer the solar panels are to the equator, the better or the closer the north and south direction are to zero, the better. Germany is one of the world leaders in solar panel power production. They are located at 51°N 9°E. They have the capacity to produce 32 GW of electricity in a day. That amount could completely power the Ohio Union for seven academic years. Columbus is located at 40°N 83°W (Anderson, 2013) which means, that on average, Columbus gets the more direct sun rays than Germany. This results in the ability to produce even more electricity from solar panels than Germany. Since it is close to the equator, Columbus has the potential to produce 230 W/m^2. This is an

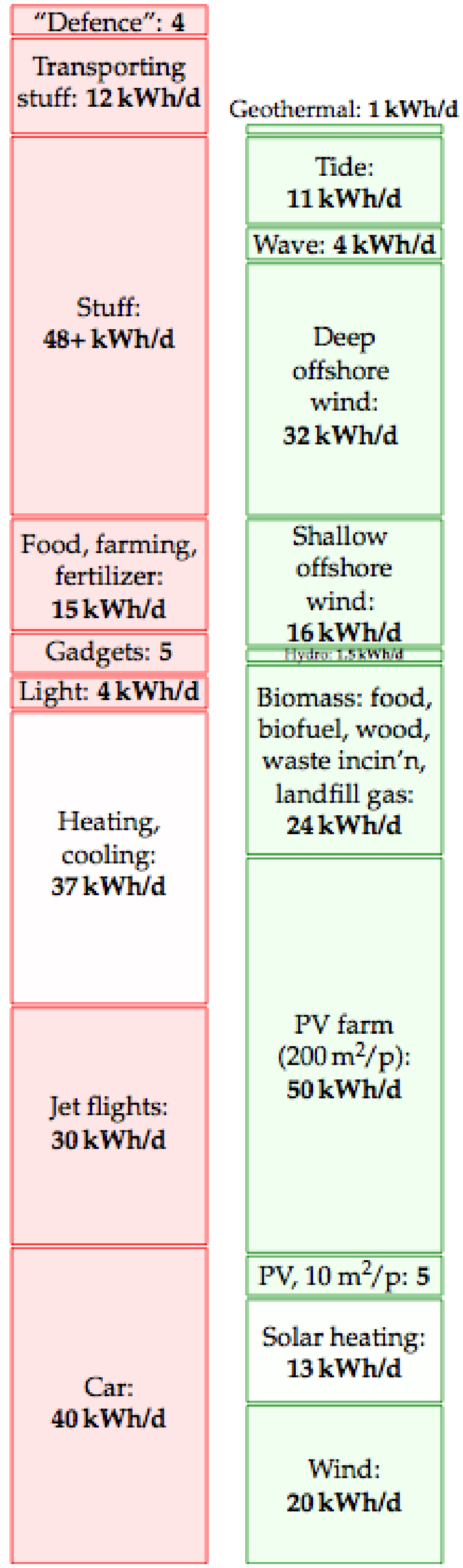

Figure 6. (Anderson, 2013): The red column is the average energy consumption of an average American. The green column represents the potential Ohio has for renewable resources.

average number because during the summer the number will be higher and during winter the number will be lower. Spring and autumn will be right around 230 W/m^2. For residential buildings, photovoltaic solar panels could produce 150 kWh/day (Anderson, 2013). It is hard to calculate the number per person for non-residential buildings but this number is helpful in thinking how much electricity can actually be produced. The average American uses 120 kWh/day. The red column is the average energy consumption of an average American (Fig. 6). The green column represents the potential Ohio has for renewable resources (Fig. 6). Solar energy is an important aspect to consider when thinking of alternative energies. Logistics and technicalities have been discussed, but another crucial component to the project design is exploring the monetary investment of solar panels.

Incentives

The government has various incentives for installing solar panels. In addition to state incentives there are federal energy Investment Tax Credit, which allows purchasers of commercial solar to take a tax credit equal to 30% of the cost of the system. There are also possible grants to apply for within the local government. The city of Columbus currently has a grant available called The Green Columbus Fund, which is used to initiate sustainable development and redevelopment. The program's budget is $2,000,000 for commercial, industrial, nonprofit, construction, multi-family residential, retail supplier, and private businesses (DSIRE).

Another incentive in place by the federal government is based upon the depreciation of a property. The federal Modified Accelerated Cost-Recovery System (MACRS) places property under ranges from 3 to 50 years in which certain properties can be depreciated. Depreciation is the annual allowance for the deterioration, or desuetude of the property, which creates an income tax deduction allowing the taxpayer to recover the cost of the property. Solar property is based within the five-year depreciation schedule. The federal *Economic Stimulus Act of 2008,* enacted in February 2008, included 50% bonus on first-year depreciation. This depreciation act was modified over the years but, in January 2013 the *American Taxpayer Relief Act of 2012* decided to extend the deadline by one year. This deadline extension allows property owners until December 31, 2013 to apply for the 50% first-year bonus depreciation allowance (DESIRE).

An additional incentive is a Performance-Based Incentive. This type of incentive can only be used for utilities that provide 25% of their electricity supply from alternative energy, therefore, this incentive does not apply to this project. Ohio State's future in solar systems is encouraged so this incentive may pertain to other projects. This specific Performance-Based incentive represents and encourages the renewable aspect of solar power. In Ohio, the incentive bundles the energy created from the panels into measurable quantities of megawatt-hours (MWh). Through this quantity, the provider is compensated for the amount of power created. The incentive for the year 2012 to 2013 is $350 per MWh, however, the rates for each year differ: for example, the year 2024 and after is $50 per MWh (DESIRE). These benefits in place by different government agencies are promotional factors, but numbers do not lie and the analysis of the costs and benefits proves that solar panels are within reach and James Clyburn, the U.S. Representative for South Carolina's 6th congressional district, could not have addressed it any better by stating,

> "But reducing harmful emissions, abating our dependence on foreign oil and developing alternative renewable energy sources have benefits that go beyond environmental health, they improve personal health, enhance national security and encourage our nation's economic viability (James Clyburn on Energy & Oil)."

<u>Cost/ Benefit Analysis</u>

There are about 31,000 available square feet of area available to use on the roof of the Ohio Union. The research began by using a solar calculator (Solar Reviews). This calculator roughly estimates the costs involved in the process of installation and the savings of the solar panels. The first step of using this calculator is to enter a zip code then select what type of utility company is the provider, what type of building the estimation is for (home v. business), and then give the average cost per month paid for electric. The average monthly cost was the addition of every monthly cost averaged for 30 days for the Union. The costs for the Union and other Ohio State buildings can be easily accessed on the energy dashboard (Buckeye Footprint). This was a great help towards this project's success.

According to the energy dashboard, the Ohio Union has used 5,297,057.19 kilowatt hours (kWh) so far this year. This number only differs in comparison to last year slightly; this is most likely due to the change from quarters to semesters. The amount spent so far this year on electricity is approximately $322,000 (Buckeye Footprint). This gives an average cost per month of electricity for the Union, which is $41,667.90.

Figure 7. 25 year cash flow (Solar Reviews)

Interestingly, the savings from the panels can provide the estimated average annual costs to attend The Ohio State University is $26,000 for an in-state student and $41,000 for an out-of-state student.

If solar panels were to be put into use, a little less than 5 percent of the electric bill could be produced because the needed roof space would be 30,604 square feet and the Ohio Union has the available roof space, 31,000 square feet, for the number of panels needed. This cost analysis is based on the estimate of 10 watts per square feet. The estimated gross cost at installation would be $1,530,175 assuming $5 per watt DC. Recall, that the government will assist the best they can and provide tax breaks such as tax credits that can save 30 percent off the gross cost. This makes the estimated net cost of installation $1,033,623. This figure may seem large, but it will pay itself off shortly after the seventh year (Fig. 7), and will have a savings of $85,686 by the end of the seventh year. The estimated 25 years savings could be from $1,049,074 to $2,727,592. This can be broken down into a smaller scale. An average annual savings would be $75,534 and an average monthly savings would be $6,295 (Solar Reviews). The amount of money saved is obvious, but the magnitude of carbon being diverted from the environment is a desire for Ohio State.

President Gee has the goal for the University to be carbon neutral by 2050; the installation of these solar panels would bring us one step closer to this goal. The greenhouse gas saved on this solar array is an impressive 7,060 tons. This equates about 14,119,000 auto miles. The national average for CO_2 emissions is 1.64 pounds per kWh (Solar Reviews). This means that since the Ohio Union uses 5,297,057.19 kWh in the past year there have been 8,687,173.79 pounds of CO_2 emitted into the environment this year alone. In comparison to cars the average estimate is 1 pound per mile driven (Solar Reviews). These statistics alone prove how solar panels can lower the carbon emissions, which is a goal among Ohio State and other Universities.

Other Universities:

Ohio State was not the only University to sign the CAP. Other universities are taking steps to becoming carbon neutral. The Environmental Protection Agency (EPA) has become involved in the campus wide race. They keep a running poll of what the Universities in each conference are doing to become carbon neutral. The first section is conference competition. The Ohio State University is ranked number one in the Big Ten with 141,000,000 kWh of green power, which powers 24 percent of our University's power use. Ohio State is followed in the Big Ten by Northwestern University, University of Wisconsin, and University of Iowa, respectively. Oregon State University is first in their conference, the Pac-12, with 95,005,040 kWh of green power; this yields 100 percent of their power. When comparing the percentages between Oregon State and Ohio State, one must keep in mind how much larger Ohio State's campus is than Oregon State. The EPA also has a section of all Universities ranked and Ohio State is second behind The University of Pennsylvania, which is putting to use 200,194,600 kWh (Green Power Partnership).

What makes Oregon State number one in Pac-12? They are already using solar systems. They currently have two lots of solar panels being put to use. The first lot is about four acres in size and provides 481 kWh of power. The second lot is about two and a half acres with the ability to produce 289 kWh. The Kelley Engineering Center has a roof system that was installed in 2004 during its construction. This system is capable of 2.4 kWh. Lastly, Oregon State has put into use a solar trailer, which is a portable device that captures and stores energy. The trailer has the potential of 7.2 kWh with a mechanical lift that moves the arrays into the best position for highest efficiency (Barnard 2011). Ohio State is doing well in the race to carbon neutrality; however, instead of second place, we should become a leader and diversify our sources of energy.

Discussion

Solar panels create social, economic, and environmental controversy amongst the public today. Many options for renewable energies receive this type of feedback. Location is a major issue when dealing with solar arrays because solar panels require an open mind to be able to handle the appearance. Solar panels can be placed upon roofs, but it is quite a challenge to hide them.

Our idea is to place the solar panels on the newer buildings, but newer buildings are meant to look extravagant and the panels may take away from that. However, it can also benefit and add to the advanced appearance of these buildings. Luckily, the Ohio Union is a fairly large building; so many people may never notice them. Having solar panels in fields may also take away from the biophilic perception of the landscape. There have been advancements to be able to hide the panels underground, but Ohio State does not have this land area.

The price of photo-voltaic cells (PVC) that can capture sunlight and turn it into an energy source are slowly falling due to demand, but they are still five times more expensive than their fossil fuel counterpart. The initial cost of installation is expensive because solar panels require a lot of square footage to be able to supply the necessary wattage. This restricts the available wattage when using roofs, but an impact would be if fields were used as a place to put solar panels instead. This takes up valuable space that can be put to use in other ways, especially fields with useful soils for farming.

Solar panels are great for the environment. Greenhouse gases will be reduced greatly, having a positive effect. Although, environmental impacts exist and can be caused by multiple events, such as, installing the panels. The fuel and power used to ship and install the panels requires a lot of labor, machinery, and fuel. Another impact would be, if fields were used as a place to position solar panels, the panels could possibly affect local species, aid in heating up the atmosphere, by reflecting the sun. Solar panels reflecting the sun can additionally cause certain effects when flying. The panels can take up valuable space that could be put to use in other ways.

The more people build solar arrays on their homes, offices, and businesses the more utility companies will not receive a gracious amount of income. The people who put up the panels benefit from the additions, not the electric companies, which can have an effect on the economy as a whole. Jobs will be lost, but if solar or other alternate energy industries expand, this creates jobs elsewhere.

Major decisions are never easy due to the gambled political, economic, and environmental outcomes. With today's modern technology there can be solutions to simple matters, but these matters are never simple. As stated before, there is not only one solution to the greenhouse gas emissions, climate change, global warming, or the diverse labels these environmental issues are known as to society. It is composed of many solutions working together towards a resolution.

Conclusion

It would be wise for the Ohio State University to construct a solar system on the roof of the Ohio Union. Such a roof would be cost-effective, reduce Ohio State's energy dependence on fossil fuels, and move the university one step closer to becoming a carbon-neutral campus by 2050. With government and utility incentive programs in place that would help reduce the initial cost of the solar system, constructing a solar roof on the Union is a realistic goal. With a little planning and design, the Union's roof could be covered with electricity-producing panels, each moving Ohio State a few watts closer to the goal of carbon-neutrality.

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